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EFFECT OF DIETARY STARCH LEVEL AND SOURCE ON PERFORMANCE, CAECAL FERMENTATION AND MEAT QUALITY IN GROWING RABBITS[1]

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ABSTRACT: To evaluate the effects of starch level and source on growth performance, caecal fermentation, and carcass and meat quality, six diets were formulated including different percentage of barley (B) or corn (C) or equal proportions of the two cereals (BC) to obtain moderate (M) or high (H) starch levels, and fed to 96 rabbits from 35 d of age until slaughter (73 d). Within starch level, B and C diets presented similar chemical composition and nutritive value while starch digestibility was higher in B diets. The starch source did not affect growth performance and meat quality and showed weak effects on caecal fermentation, apart from a higher proportion of valerate in rabbits fed diets C ($P<0.05$). According to cereal inclusion rate, M diets were lower in starch (17.0 *vs* 20.6% DM) and digestible energy concentration (12.1 *vs* 12.6 MJ/kg DM) and higher in fibre concentration (ADL: 4.7 *vs* 3.9% DM) than H diets. The starch level affected growth performance: H diets stimulated weight gain (41.7 *vs* 43.5 g/d; $P<0.05$) and improved feed conversion ($P<0.001$) in comparison with M diets but did not affect health status or caecal fermentation. High-starch diets also increased dressing percentage (60.9 *vs* 61.5%; $P<0.05$), and cooking losses and share press force of meat.

INTRODUCTION

A low dietary amount of starch is recommended in the post-weaning period (Lebas and Maitre, 1989; Maertens, 1992) in order to reduce digestive problems linked to the incomplete development of the enzymatic system in young rabbits and their inability to digest starch completely (Cheeke, 1987; Blas *et al.*, 1990; Scapinello *et al.*, 1999). The outbreak of epizootic enterocolitis in Europe has further stimulated the reduction of dietary starch and the increase of fibre fractions as an enterocolitis prevention method during weaning and fattening, with a consequent impairment of diet nutritive value and feed conversion (Gidenne, 2000; Licois *et al.*, 2000).

Barley is the cereal most commonly used in rabbit diets in Europe, traditionally included in the measure of 15-25% of the diets, and preferred to corn because of its lower frequency of mycotoxin contamination and higher starch digestibility. This latter avoids high starch ileal escape and overflow in the caecum with negative consequences on digestive physiology, caecal fermentation and health status (Gidenne and Perez 1993a, 1993b; Blas and Gidenne, 1998). Studies on the effects of starch levels and sources in growing rabbits gave sometimes controversial results, however (De Blas *et al.*, 1986; Parigi Bini *et al.*, 1990; Blas *et al.*, 1994; Xiccato *et al.*, 1998). Moreover, few data are available on their effects on carcass and meat quality (Xiccato, 1999; Nizza and Moniello, 2000).

The aim of the present study was to evaluate the effect of two starch levels (17 *vs* 21% DM) and two starch sources (barley and corn) on growth performance, caecal fermentation, and carcass and meat quality in growing rabbits.

MATERIALS AND METHODS

Animals and diets

Ninety-six rabbits of both genders from a hybrid line (Grimaud Frères, France) were reared in individual cages from 35 d of age until slaughter, at 73 d. The rabbits were kept in a brick shed equipped with a forced heating system to maintain a minimum temperature of 18°C and submitted to a natural photoperiod.

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Four diets (B-M, C-M, B-H, C-H) were formulated by using barley (B) or Corn (C) as main starch source included at different rates to obtain moderate (M) or high (H) starch levels (Table 1). Dilution technique was used to obtain two more diets: BC-H diet (0.5 B-H + 0.5 C-H) and BC-M diet (0.5 B-M + 0.5 C-M). From 35 d of age until slaughter, rabbits were divided into six groups (16 rabbits each), homogeneous in average weight and variability, and given *ad libitum* access to the six experimental diets.

Individual live weight and feed intake were recorded three times a week. The health status of rabbits was controlled daily. The rabbits were considered ill when evidencing clear signs of diarrhoea as well as strong reduction of feed intake. In the calculation of morbidity, the ill rabbits were considered only once and the dead animals were considered only in the calculation of mortality. The sanitary risk was calculated as the sum of morbidity and mortality (BENNEGADI *et al.*, 2000). To prevent epizootic enterocolitis, from 39 to 45 days of age, drinking water was supplemented with 150 mg/ l aminosidin sulphate and 75 mg/ l tiamuline hydrogen fumarate.

Four rabbits died and six were excluded from the trial due to respiratory and digestive problems that caused severe growth reduction. Therefore the number of rabbits was 15, 14, 14, 13, 15, and 15 for groups B-M, BC-M, C-M, B-H, BC-H, and C-H, respectively.

Table 1: Ingredients (%) of experimental diets.

	Experimental diets					
	B-M	BC-M	C-M	B-H	BC-H	C-H
Ingredients, %						
Barley meal	17.4	8.7	0.0	27.4	13.7	0.0
Corn meal	0.0	7.5	15.0	0.0	12.0	24.0
Alfalfa meal 17%CP	32.4	33.2	34.0	22.4	23.7	25.0
Wheat bran	25.5	25.5	25.5	20.5	20.5	20.5
Dried beet pulp	10.0	10.0	10.0	10.0	10.0	10.0
Soybean meal 44%CP	4.6	4.8	5.0	7.1	7.3	7.5
Sunflower meal 30%CP	4.6	4.8	5.0	7.1	7.3	7.5
Animal fat	1.5	1.5	1.5	1.5	1.5	1.5
Cane molasses	2.2	2.2	2.2	2.2	2.2	2.2
Limestone	0.20	0.20	0.20	0.20	0.20	0.20
Dibasic calcium phosphate	0.55	0.55	0.55	0.55	0.55	0.55
Salt	0.45	0.45	0.45	0.45	0.45	0.45
Vitamin-mineral premix	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine	0.10	0.10	0.10	0.10	0.10	0.10
HCl lysine	0.10	0.10	0.10	0.10	0.10	0.10
Coccidiostatic	0.10	0.10	0.10	0.10	0.10	0.10

B: barley diet, BC: barley+corn diet, C: corn diet, M: moderate starch level, H: high starch level.

Digestibility trial

The apparent digestibility of DM and nutrients and the DE concentration of the experimental diets were measured in a digestibility assay carried out on 60 rabbits among the 96 on trial (10 animals of both genders per diet) according to the European standardised method (PEREZ *et al.*, 1995). The digestibility trial started at 49 days of age with a 4-d collection period.

Commercial slaughter and carcass and meat quality recordings

The rabbits were slaughtered at 73 d of age in a commercial slaughterhouse and 24 hours later the chilled carcasses were dissected according to BLASCO *et al.* (1996) procedures. Cooking losses and shear press force were measured on a hind leg following the procedures described by XICCATO *et al.* (1994). An Instron machine (model 1140) equipped with a Warner-Bratzler device was used to measure shear press force.

Caecal content sampling and analysis

At slaughter, gastrointestinal tracts were removed by all rabbits. About one hour after slaughter, the pH of the caecal content was measured using a pH-meter (HI 9025C, Hanna Instruments, Sarmeola di Rubano, Padova, Italy) equipped with a combined Ingold electrode (406 M3). The caecal content was then collected, put into plastic bottles, diluted with 15% HPO_3 (25% wt/wt), and stored at –20°C until chemical analyses.

Chemical analysis

Diets and faeces were analysed by AOAC (2000) methods following harmonised procedures (EGRAN, 2001). Ether extract was determined after acid-hydrolysis treatment. Fibre fractions were analysed by the GOERING and VAN SOEST (1970) method, as modified by ROBERTSON and VAN SOEST (1981), using the sequential procedure. The NDF determination was carried out using a thermo-resistant amylase (Thermamyl L120, Novo Nordisk, Denmark). Starch concentration was measured by an enzymatic kit (Boehring Mannheim, Gmbh, Mannheim, Germany).

The thawed samples of caecal content were centrifuged for 10 min at 9,000 *g*. Caecal N-ammonia was determined on the supernatant by pH-meter (PHM 84, Research pH-meter, Radiometer, Copenhagen, Denmark) equipped with ammonia-specific electrode (mod. 9512, Orion Research Incorporated, Boston, USA). Volatile fatty acid (VFA) concentration was measured on the supernatant by gas-chromatography (HRGC 5300 Carlo Erba, Milano, Italy) on a cross bond capillary column (25 m x 0.32 mm I.D., 3.5 mm film thickness) (JRX, Mega, Milano, Italy) using the method of OSL (1988).

Statistical analysis

The data recorded were analysed by a two-way ANOVA (2 starch levels x 3 starch sources). Because no interaction was observed between the two experimental factors, the results were reported as means of the main effects. The GLM procedure of SAS (SAS, 1991) was used for all analyses. The Bonferroni *t* statistics was used to compare means by group of diets. The χ^2 test was used to compare mortality and morbidity among treatments.

RESULTS

Starch and fibre concentration accounted for the main differences in chemical composition between M and H diets, as the consequence of the substitution of alfalfa meal with cereals (Table 2). Starch was lower (-3.6 units) and crude fibre higher (+1.6 units) in M diets than in H diets. The average starch to ADF ratio was 0.84 for M diets and 1.17 for H diets. Dry matter digestibility was lower in M diets than in H diets (64.1% *vs* 68.2%; $P<0.001$) as was also DE concentration (12.1 *vs* 12.6 MJ/kg DM) (Tables 2 and 3). The DP/DE ratio was similar in the two groups of diets and consistent with recommendations.

The substitution of barley by corn did not produce any substantial change in chemical composition but a higher starch level in C-H diet than in B-H diet (21.3 *vs* 19.7% DM). Barley-based diets showed higher starch digestibility ($P<0.001$) than corn-based diets. The starch digestibility of BC diets, obtained by mixing in equal parts B and C diets, was similar to C diets.

Growth performance of rabbits was affected by the dietary starch level (Table 4). At the end of the trial, rabbits fed high-starch diets were heavier compared to rabbits fed low-starch diets ($P<0.10$) due to the higher daily weight gain (41.7 *vs* 43.5 g/d; $P<0.05$). Daily feed intake was not significantly affected, while feed conversion was more favourable in rabbits fed H diets ($P<0.001$). The starch source did not affect growth performance.

As what concerns the health status, the same number of rabbits fed M or H diets were excluded from the trial or died. Morbidity was numerically higher in rabbits fed high-starch diets (6 animals, 12.5%) compared to rabbits fed low-starch diets (2 animals, 4.2%) but the difference was not significant ($P>0.05$).

At slaughter, dressing percentage was higher ($P<0.05$) in rabbits fed H diets due to the lower gut incidence (Table 5). The reference carcass was heavier in H treatment and the hind leg meat showed higher

Table 2: Chemical composition and nutritive value of experimental diets.

	Experimental diets					
	B-M	BC-M	C-M	B-H	BC-H	C-H
Chemical composition						
Dry matter, %	90.4	90.5	90.4	90.1	90.0	90.2
Crude protein, % DM	16.3	16.5	16.2	16.8	16.9	16.8
Ether extract, % DM	4.1	4.3	4.3	4.3	4.3	4.5
Crude fibre, % DM	17.1	17.4	17.3	15.9	15.7	15.3
Ash, % DM	8.3	8.1	8.3	7.8	7.5	7.4
NDF, % DM	41.4	38.5	39.7	37.2	35.5	33.4
ADF, % DM	20.5	19.9	20.4	17.9	17.6	17.5
ADL, % DM	4.7	4.7	4.7	4.1	3.7	3.8
Starch, % DM	17.2	16.6	17.2	19.7	20.8	21.3
Starch/ADF ratio	0.84	0.83	0.84	1.10	1.18	1.22
Gross energy, MJ/kg DM	18.63	18.61	18.60	18.67	18.63	18.77
Nutritive value						
Digestible energy (DE), MJ/kg DM	12.1	12.2	12.1	12.5	12.6	12.7
Digestible protein (DP), g/kg DM	125	127	122	131	133	129
DP/DE (g/MJ)	10.3	10.5	10.1	10.5	10.5	10.2

B: barley diet, BC: barley+corn diet, C: corn diet, M: moderate starch level, H: high starch level.

Table 3: Apparent digestibility of experimental diets

	Starch level			Starch source				
	M	H	*P*- value	B	BC	C	*P*- value	RSD
Rabbits	30	30		20	20	20		
Digestibility coefficients, %								
Dry matter	64.1	68.1	<0.001	65.6	66.3	66.6	NS	2.4
Organic matter	64.7	69.0	<0.001	66.3	67.0	67.2	NS	2.4
Crude protein	76.4	77.6	<0.001	77.3	77.6	76.3	NS	2.9
Ether extract	84.3	86.3	<0.001	85.0	85.3	85.6	NS	2.1
Crude fiber	26.5	29.6	<0.001	27.3	28.7	28.2	NS	4.1
NDF	36.1	36.5	NS	37.6	35.6	35.6	<0.10	4.5
ADF	22.7	22.7	NS	22.2	22.1	23.8	NS	4.1
Starch	98.9	98.7	<0.001	99.4[a]	98.5[b]	98.5[b]	<0.001	0.2
Gross energy	65.2	67.5	<0.001	66.0	66.5	66.4	NS	2.5

M: moderate starch level, H: high starch level, B: barley, BC: barley+corn, C: corn.
RSD: residual standard deviation.
NS: not significant.

cooking losses ($P<0.01$) and shear press force ($P<0.05$) compared to M treatment.

Gut incidence was significantly lower in the BC treatment compared to other treatments ($P<0.01$) and a significant effect of the starch source was recorded also on dissectible fat, lower in rabbits fed BC diets ($P<0.05$).

The administration of diets at different starch levels did not modify the characteristics of the caecal content (Table 6). Caecal pH tended to be slightly higher in rabbits fed M diets ($P<0.10$) while neither total VFA production nor VFA proportions were affected. The starch source showed weak effects on caecal content characteristics, apart from a higher proportion of valerate in rabbits fed C diets ($P<0.05$).

Table 4: Growth performance of growing rabbits.

	Starch level [1]			Starch source [2]				
	M	H	*P*-value	B	BC	C	*P*-value	RSD [3]
Rabbits	43	43		28	29	29		
Live weight at 35 d, g	933	935	0.90	933	926	943	0.68	74
Live weight at 73 d, g	2517	2589	0.06	2567	2549	2543	0.87	179
Daily weight gain, g/d	41.7	43.5	0.04	43.0	42.7	42.1	0.72	4.2
Daily feed intake, g/d	120	117	0.23	121	118	116	0.24	11
Feed conversion	2.88	2.69	<0.001	2.81	2.78	2.76	0.53	0.18

[1] M = moderate starch level; H = high starch level. [2] B = barley; BC = barley+corn; C = corn. [3] RSD = residual standard deviation.

Table 5: Slaughter results, carcass and meat quality.

	Starch level			Starch source				
	M	H	*P*-value	B	BC	C	*P*-value	RSD
No. rabbits	43	43		28	29	29		
Slaughter weight (SW), g	2427	2503	<0.05	2478	2458	2460	NS	170
Transport losses, %	3.31	3.57	NS	3.4	3.6	3.3	NS	1.2
Cold carcass, g	1478	1539	<0.01	1511	1512	1503	NS	107
Cold dressing percentage, %SW	60.9	61.5	<0.05	61.0	61.6	61.1	NS	1.2
Gut incidence, % SW	17.3	16.8	<0.05	17.3[b]	16.5[a]	17.4[b]	<0.01	1.1
Reference carcass (RC), g	1236	1286	<0.01	1264	1266	1253	NS	92
Dissectible fat, %RC	2.65	2.76	NS	2.82[a]	2.45[b]	2.85[a]	<0.05	0.6
Hind legs, %RC	33.1	33.2	NS	33.1	33.2	33.2	NS	1.0
Longissimus dorsi m., %RC	12.5	12.7	NS	12.6	12.5	12.6	NS	0.9
Muscle/bone of hind leg	4.87	4.79	NS	4.92	4.83	4.73	NS	0.61
Cooking losses of hind leg, %	24.0	25.0	<0.01	24.6	24.3	24.6	NS	1.8
Shear press force, kg/cm2	1.00	1.11	<0.05	1.05	1.05	1.07	NS	0.22

M: moderate starch level, H: high starch level, B: barley, BC: barley+corn, C: corn.
RSD: residual standard deviation.
NS: not significant.

DISCUSSION

Effect of starch level

The average concentrations of starch in M diets (17.0% DM) and H diets (20.6% DM) were above the most recent reference value for post-weaning period (<15% DM), while ADL was below the value (5% DM) recommended to reduce sanitary risk (GIDENNE, 2000). However, all diets were balanced and consistent with general recommendations for growing rabbits (DE BLAS and MATEOS, 1998; NICODEMUS *et al.*, 1999).

In the conditions of our trial, epizootic enterocolitis did not occur and health status was not affected by the dietary treatment. Both the preventive antibiotic treatment and the number of animals, quite low for suitable evaluation of mortality and morbidity, could have accounted for the absence of a starch level effect on health status. On higher numbers of rabbits, controversial results were reported by other authors (BLAS *et al.*, 1994; GIDENNE *et al.*, 2000). LEBAS and MAITRE (1989) described a significant increase of mortality when rabbits were fed high starch (25%) diets in the first period of growth (from 21 to 45 d of age), during which digestive enzymatic equipment is still incomplete. Also DEBRAY *et al.* (2002) observed higher mortality rate in rabbits fed a high-starch/low-fibre diet in the weaning period, but morbidity was higher for the rabbits fed the low-starch/high-fibre diet from 32 to 44 d of age.

When high-starch diets were fed to rabbits older than 35 d of age under more balanced nutritional conditions and respecting minimum fibre levels, no significant difference was recorded on health status (PARIGI BINI *et al.*, 1990; XICCATO *et al.*, 1998). According to DE BLAS *et al.* (1986), which investigated a wide range of starch to fibre ratio, minimum values of ADF 15.3%, crude fibre 11.7% and ADL 4.1% DM were necessary to reduce mortality due to diarrhoea. The occurrence of diarrhoea was attributed to a low digestive transit rate due to insufficient dietary fibre, while no direct effect of starch concentration was revealed.

In our trial, the increase of DE concentration in H diets stimulated growth rate without affecting feed intake, while usually the former is not affected and the latter is reduced, due to the chemiostatic regulation of appetite (PARTRIDGE, 1986; PARIGI BINI and XICCATO,

Table 6: Characteristics of caecal content.

	Starch level			Starch source				
	M	H	*P*-value	B	BC	C	*P*-value	RSD
Rabbits	43	43		28	29	29		
pH	6.14	6.08	NS	6.12	6.08	6.12	NS	0.17
N-ammonia, mmol/l	13.2	10.7	NS	10.5	13.6	11.9	NS	5.1
Total VFA, mmol/l	68.0	71.1	NS	66.7	74.7	67.2	NS	16.0
Acetic acid, %	79.4	78.7	NS	79.5	79.5	78.2	NS	3.5
Propionic acid, %	4.8	4.8	NS	4.7	4.7	4.9	NS	0.8
Butyric acid, %	14.9	15.5	NS	14.9	14.9	15.9	NS	3.2
Valeric acid, %	0.9	1.0	NS	0.9[a]	0.9[a]	1.1[b]	<0.05	0.2
C3/C4 ratio	0.33	0.32	NS	0.33	0.33	0.32	NS	0.08

M: moderate starch level, H: high starch level., B: barley, BC: barley+corn, C: corn.
RSD = residual standard deviation.

1998). The continuously increasing trend towards low-energy diets, as a mean to reduce digestive disorders, needs careful evaluation due to the importance of improving efficiency in order to reduce animal waste in the environment.

As what regards slaughter results, the higher gut content in rabbits fed M diets depended on the higher dietary fibre concentration and explained the lower dressing percentage, as stated by other authors (DE BLAS *et al.*, 1986, 1999; GIDENNE, 1992; PARIGI BINI *et al.*, 1994).

Other traits of carcass and meat were weakly affected by dietary starch level. In fact, rabbit carcass and meat quality substantially changed only when diets presented great nutrient excess or lack, being the ontogenetic factors (slaughter weight and age, sex, etc.) more effective (PARIGI BINI *et al.*, 1992; OUHAYOUN, 1998; XICCATO, 1999).

Dietary starch level weakly affected caecal fermentation, with a slight reduction of caecal pH in rabbits fed high-starch diets, as described by BELLIER and GIDENNE (1996), and without effects on ammonia, total VFA and VFA proportions. These results may be ascribed both to the low difference in starch concentration between M and H diets, both to the high ileal starch digestibility which limited the starch flow in the caecum. GIDENNE *et al.* (2000) investigated a wider range of dietary starch (10 to 30% DM) and ADF (20 to 12% DM) and found that when increasing the starch to fibre ratio, the total VFA and the proportion of acetate decreased while butyrate proportion increased. Also PARIGI BINI *et al.* (1990) observed higher butyrate proportion when increasing starch supply from 17 to 25% DM.

Effect of starch source

Studies on starch sources in rabbit feeding are limited compared to those on starch level, and mainly dealt with barley, wheat, corn and pea (BLAS *et al.*, 1990; BLAS and GIDENNE, 1998; GUTIÉRREZ *et al.*, 2002).

Previous studies found that digestibility of corn starch is somewhat lower than barley starch (BLAS *et al.*, 1990; GIDENNE and PEREZ, 1993a and 1993b), as confirmed also in our study. However, digestive problems can hardly be related to the major ileal starch overflow that results when rabbits are fed corn (GIDENNE *et al.*, 2000). In fact, we did not observe any significant difference in mortality or morbidity rate in the three groups of rabbits receiving barley, corn+barley and corn diets (6, 5, and 7 morbid rabbits corresponding to 19%, 16% and 22% of morbidity.

Similarly to our results, NIZZA and MONIELLO (2000) did not report any effect of the starch source on growth performance and meat properties, confirming the above-mentioned low susceptibility of carcass and meat quality to dietary factors.

The weak effect of starch source on caecal content characteristics was described also by BELENGUER *et al.* (2000) and was limited to a higher proportion of valerate in the caecum of rabbits fed corn diets in comparison with barley diets. Despite the low amount and difference between diets, the higher quantity of indigested starch reaching the caecum when feeding corn diets likely accounted for this result, since the production of valerate has been associated with the activity of the amylolitic and proteolitic microflora (PADHILA *et al.*, 1995).

CONCLUSIONS

The increase of dietary starch from around 17 to 21% DM, with the to starch/ADF ratio raising from 0.84 to 1.17, increased diet nutritive value and feed efficiency without affecting either caecal fermentation activity or the health status of growing rabbits. The suitable supply of dietary fibre and, perhaps, the preventive antibiotic treatment may account for this latter result.

Using corn in replacement of barley or equal proportions of the two cereals had no effect on growth performance and sanitary risk. Both starch level and source did not affect carcass and meat quality.

The nutritive value of diets for growing rabbits can be increased by the inclusion of 20% starch, as barley or corn or both, providing good growth performance and improving feed efficiency, without substantial changes of fermentation caecal activity and sanitary risk.

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REFERENCES

AOAC, 2000. Official Methods of Analysis. *17th ed. Assoc. Offic. Anal. Chem.*, Arlington, VA.

BELENGUER A., FONDEVILA M., BALCELLS J., TORRE C., 2000. Effect of the source and level of cereal in diet on the rabbit caecal environment and microbial population. *in*: *Proc. 7th World Rabbit Congress, vol.* ***C****, 95-100.*

BELLIER R., GIDENNE T., 1996. Consequences of reduced fibre intake on digestion, rate of passage and caecal microbial activity. *Br. J. Nutr.,* ***75****, 353-363.*

BENNEGADI N., GIDENNE T., LICOIS D., 2000. Non-specific enteritis in the growing rabbit: detailed description and incidence according to fibre deficiency and sanitary status. *in*: *Proc. 7th World Rabbit Congress, vol.* ***C****, 109-117.*

BLAS E., GIDENNE T., 1998. Digestion of starch and sugars. *in*: *De Blas C., Wiseman J. (ed). The Nutrition of the Rabbit. CABI Publishing. CAB International, Wallingford Oxon, UK, 17-38.*

BLAS E., CERVERA C., FERNÁNDEZ CARMONA J., 1994. Effect of two diets with varied starch and fibre levels on the performances of 4-7 weeks old rabbit. *World Rabbit Sci.,* ***2****, 117-121.*

BLAS E., FANDOS J.C., CERVERA C., GIDENNE T., PEREZ J.M., 1990. Effet de la nature et du taux d'amidon sur l'utilisation digestive de la ration chez le lapin, au cour de la croissance. *in*: *Proc. 5èmes Journées de la Recherche Cunicole en France, Paris, France December 1990, vol.* ***II****, Comm. 50.*

BLASCO A., OUHAYOUN J., MASOERO G., 1996. Harmonization of criteria and terminology in rabbit meat research. *World Rabbit Sci.,* ***1****, 3-10.*

CHEEKE P.R., 1987. Rabbit Feeding and Nutrition. *Academic Press, Inc. LTD., London, UK.*

DE BLAS J.C., MATEOS G.G., 1998. Feed Formulation. *in: De Blas C., Wiseman J. (ed). The Nutrition of the Rabbit. CABI Publishing. CAB International, Wallingford Oxon, UK, 241-253.*

DE BLAS J.C., GARCÍA J., CARABAÑO R., 1999. Role of fibre in rabbit diets. A review. *Ann. Zootech.,* ***48****, 3-13.*

DE BLAS J.C., SANTOMÁ G., CARABAÑO R., FRAGA M.J., 1986. Fiber and starch levels in fattening rabbit diets. *J. Anim. Sci.,* ***63****, 1897-1904.*

DEBRAY L., FORTUN-LAMOTHE L., GIDENNE T., 2002. Influence of low dietary starch/fibre ratio around weaning on intake behaviour, performance and health status of young and rabbit does. *Anim. Res.,* ***51****, 63-75.*

EGRAN – EUROPEAN GROUP ON RABBIT NUTRITION – GIDENNE T., PEREZ J.M., XICCATO G., TROCINO A., CARABAÑO R., VILLAMIDE M.J., BLAS E., CERVERA C., FALCAO-E-CUNHA L., MAERTENS L., 2001. Technical note: attempts to harmonize chemical analyses of feeds and faeces, for rabbit feed evaluation. *World Rabbit Sci.,* ***9****, 57-64.*

GIDENNE T., 1992. Effect of fibre level, particle size and adaptation period on digestibility and rate of passage as measured at the ileum and in the faeces in the adult rabbit. *Br. J. Nutr.,* ***67****, 133-146.*

GIDENNE T., 2000. Recent advances in rabbit nutrition: emphasis on fibre requirements. A review. *World Rabbit Sci.,* ***8****, 23-32.*

GIDENNE T., PEREZ J.M., 1993a. Effect of dietary starch origin on digestion in the rabbit. 1. Digestibility measurements from weaning to slaughter. *Anim. Feed Sci. Technol.,* ***42****, 237-247.*

GIDENNE T., PEREZ J.M., 1993b. Effect of dietary starch origin on digestion in the rabbit. 2. Starch hydrolysis in the small intestine, cell wall degradation and rate of passage measurement. *Anim. Feed Sci. Technol.,* ***42****, 249-257.*

GIDENNE T., PINHEIRO V., FALCAO-E-CUNHA L., 2000. A comprehensive approach of the rabbit digestion: consequences of a reduction of dietary fibre supply. *Livest. Prod. Sci.,* ***64****, 225-237.*

GOERING H.K., VAN SOEST P.J., 1970. Forage Fiber Analyses (Apparatus, Reagents, Procedures, and Some Applications). *Agric. Handbook No. 379. ARS, USDA, Washington, DC, USA.*

GUTÍERREZ I., ESPINOSA A., GARCÍA J., CARABAÑO R., DE BLAS J.C., 2002. Effects of starch and protein sources, heat processing, and exogenous enzymes in starter diets for early weaned rabbits. *Anim. Feed Sci. Technol.*, ***98***, *175-186.*

LEBAS F., MAITRE I., 1989. Alimentation de presevrage. Etude d'un aliment riche en énergie et pauvre en protéines. Résultats de 2 essais. *Cuniculture, **16(3)**, 135-140.*

LICOIS, D., COUDERT P., CERÉ N., VAUTHEROT J. F., 2000. Epizootic enterocolitis of the rabbit: review of current research. *Proc. 7th World Rabbit Congress, vol. **B**, 187-194.*

MAERTENS L., 1992. Rabbit nutrition and feeding: a review of some recent developments. *J. Appl. Rabbit Res.*, ***15***, *889-913.*

NICODEMUS N., CARABAÑO R., GARCÍA J., MÉNDEZ J., DE BLAS C., 1999. Performance response of lactating and growing rabbits to dietary lignin content. *Anim. Feed Sci. Technol.*, ***80***, *43-540.*

NIZZA A., MONIELLO G., 2000. Meat quality and caecal content characteristics of rabbit according to dietary content and botanical origin of starch. *World Rabbit Sci.*, ***8***, *3-9.*

OSL F., 1988. Bestimmung der niederen freien Fettsauren im Hart- und Schnittkäse mit der Head-Space Gaschromatographie. *Deutsche Molkerei Zeitung **109(45)**, 1516-1518.*

OUHAYOUN J., 1998. Influence of the diet on rabbit meat quality. *in: De Blas C., Wiseman J. (ed). The Nutrition of the Rabbit CABI Publishing. CAB International, Wallingford Oxon, UK, 177-195.*

PADHILA M.T.S., LICOIS D., GIDENNE T., CARRE B., FONTY G., 1995. Relationship between microflora and caecal fermentation in rabbits before and after weaning. *Reprod. Nutr. Dev.*, ***35***, *375-386.*

PARIGI BINI R., XICCATO G., 1998. Energy metabolism and requirements. *in: De Blas C., Wiseman J. (ed). The Nutrition of the Rabbit CABI Publishing. CAB International, Wallingford Oxon, UK, 103-131.*

PARIGI BINI R., XICCATO G., CINETTO M., 1990. Influenza del contenuto di amido alimentare sulla produttività, sulla digeribilità e sulla composizione corporea di conigli in accrescimento. *Zoot. Nutr. Anim.*, ***16***, *271-282.*

PARIGI BINI R., XICCATO G., CINETTO M., DALLE ZOTTE A., 1992. Effetto dell'età, del peso di macellazione e del sesso sulla qualità della carcassa e della carne cunicola. 1. Rilievi di macellazione e qualità della carcassa. *Zoot. Nutr. Anim.*, ***18***, *157-172.*

PARIGI BINI R., XICCATO G., DALLE ZOTTE A., CARAZZOLO A., 1994. Effets de différent niveaux de fibre alimentaire sur l'utilisation digestive et la qualité bouchère chez le lapin. *in: Proc. 6èmes Journées de la Recherche Cunicole, La Rochelle, France Décembre 1994, vol. 2, 347-354.*

PARTRIDGE G.G., 1986. Meeting the protein and energy requirements of the commercial rabbit for growth and reproduction. *in: Proc. 4th World Congress of Animal Feeding, Madrid, vol. **IX**, 271-277.*

PEREZ J. M., LEBAS F., GIDENNE T., MAERTENS L., XICCATO G., PARIGI BINI R., DALLE ZOTTE A., COSSU M.E., CARAZZOLO A., VILLAMIDE M.J., CARABAÑO R., FRAGA M.J., RAMOS M.A., CERVERA C., BLAS E., FERNÁNDEZ CARMONA J., FALCAO-E-CUNHA L., BENGALA FREIRE J., 1995. European reference method for in vivo determination of diet digestibility in rabbits. *World Rabbit Sci.*, ***3***, *41-43.*

ROBERTSON J.B., VAN SOEST P.J., 1981. The detergent system of analysis and its application to human foods. *in: James W.P.T. and Theander O. (ed). The analysis of dietary fiber in food. Marcel Dekker, Inc., New York and Basel, 142-143.*

SAS STATISTICAL ANALYSIS SYSTEM INSTITUTE INC., 1991. *User's Guide, Statistics, Version 6.03. Edition SAS Institute Inc., Cary, NC.*

SCAPINELLO C., GIDENNE T., FORTUN-LAMOTHE L., 1999. Digestive capacity of the rabbit during the post-weaning period, according to the milk/solid feed intake pattern before weaning. *Reprod. Nutr. Dev.*, ***39***, *423-432.*

XICCATO G., 1999. Feeding and meat quality in rabbits: a review. *World Rabbit Sci.*, ***7***, *75-86.*

XICCATO G., COSSU M.E., TROCINO A., QUEAQUE P.I., 1998. Influence du rapport amidon/fibre et de l'addition de graisse en post-sevrage sur la digestion, les performances zootechniques et la qualité bouchère du lapin. *in: Proc. 7èmes Journées de la Recherche Cunicole, Lyon, France May 1998, 154-162.*

XICCATO G., PARIGI BINI R., DALLE ZOTTE A., CARAZZOLO A., 1994. Effect of age, sex and transportation on the composition and sensory properties of rabbit meat. *in: Proc. 40th International Congress Meat Science and Technology, The Hague, The Netherlands, W-2.02.*